

CLAIMS

We claim:

1. A method for predicting the failure of a component, the method comprising:
 - obtaining a Finite Element Model (FEM) of a component;
 - 5 analyzing said FEM to obtain stresses at nodes of said FEM;
 - identifying a subset of said nodes as significant nodes based on said stresses;
 - determining a Representative Volume Element (RVE) for at least one of said significant nodes;
 - developing an RVE microstructure-based failure model for at least one said RVE;
 - 10 simulating a component life using at least one RVE microstructure-based failure model, said simulating producing a result related to said component life;
 - performing said simulating a plurality of times to produce results related to component life;
 - preparing statistics using said results;
- 15 comparing said statistics to a probability of failure (POF) criteria to determine whether said performing predicted failure for said component.
2. The method of claim 1, wherein said failure is due to fatigue.
- 20 3. The method of claim 1, wherein each said RVE microstructure-based failure model comprises at least one random variable and wherein probabilistic methods are used to provide values for said at least one random variable.
4. The method of claim 1, wherein said simulating further comprises:
 - 25 establishing an RVE life for each said RVE; and
 - using each said RVE life to produce a result related to said component life.
5. The method of claim 1, said developing comprising:
 - 30 identifying a material microstructure in said RVE;
 - characterizing how damage interacts with said material microstructure to provide at least one damage mechanism; and
 - creating a failure model for said material microstructure based on said at least one damage mechanism, said creating comprising:
 - 35 finding a sequence said at least one damage mechanism works to damage said material microstructure;

getting for each said at least one damage mechanism one of a group of models consisting of: a crack nucleation model, a short crack growth model, and a long crack growth model; and

5 linking said models to produce said RVE microstructure-based failure model based on information from said identifying, characterizing, and finding.

6. The method of claim 5, said characterizing further comprising:
determining said material microstructure's mechanical characteristics; and
10 determining said material microstructure's bulk elastic material characteristics.

7. The method of claim 5, wherein said finding comprises:
determining how many of said at least one damage mechanism are crack nucleation mechanisms;
15 determining how many of said at least one damage mechanism are short crack growth mechanisms;
determining how many of said at least one damage mechanism are long crack growth mechanisms; and
developing a strategy for linking said crack nucleation, short crack growth, and long
20 crack growth mechanisms.

8. The method of claim 1, said simulating further comprising:
determining an RVE life for each said RVE, said determining an RVE life comprising:
25 evaluating a statistically determined number of nucleation sites within said RVE utilizing probabilistic methods.

9. The method of claim 8, wherein said probabilistic methods comprise Monte Carlo (MC) methods.
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10. The method of claim 1, said identifying further comprising
obtaining a statistical distribution of said stresses at said significant nodes and said
simulating a component further comprising:
establishing an RVE life for each said RVE using probabilistic methods and said
35 statistical distribution.

11. The method of claim 10, wherein said probabilistic methods comprise Monte Carlo methods.

12. The method of claim 1, wherein said component has regions of similar geometric detail and said simulating further comprises adding a spatial correlation for said regions.
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13. The method of claim 10, wherein said component has regions of similar geometric detail and said simulating further comprises adding a spatial correlation for said regions.

10 14. The method of claim 5, wherein said RVE microstructure-based failure model comprises random variables and wherein probabilistic methods are used to provide values for said random variables.

15. The method of claim 14, wherein said probabilistic methods rely upon simulation-based methods.
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16. The method of claim 15, wherein said simulation-based methods are direct methods selected from a group consisting of: Monte Carlo (MC) methods, and importance sampling methods.

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17. The method of claim 5, wherein said getting comprises developing at least one of said group of models.

18. The method of claim 5, wherein said getting further comprises:

25 identifying variables that are important in the description of each said at least one damage mechanism;

relating said variables that are important to one of a group of damage mechanisms consisting of: a crack nucleation mechanism, a short crack growth mechanism, and a long crack growth mechanism to form, respectively, one of a
30 group of models consisting of: a crack nucleation model, a short crack growth model, and a long crack growth model; and

defining output from said one of a group of models.

19. An apparatus for predicting the failure of a component comprising:

35 a central processing unit (CPU);

an output device for displaying simulated fatigue results;
an input device for receiving input;
and a memory comprising:

instructions for receiving input comprising a component's material
characteristics, a Finite Element Model of said component; and at least one
Representative Volume Element (RVE) microstructure-based failure model;

instructions for predicting failure of said component comprising:

analyzing said FEM to obtain stresses at nodes of said FEM;

identifying a subset of said nodes as significant nodes based on said
10 stresses;

determining an RVE for at least one of said significant nodes;

simulating a component using at least one RVE microstructure-based
failure model, said simulating producing a result related to component life;

15 performing said simulating a plurality of times to produce results
related to component life;

preparing statistics using said results; and

comparing said statistics to a probability of failure (POF) criteria to
determine whether said performing predicted failure for said component; and
instructions for displaying a result from said predicting.

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20. The apparatus of claim 19, wherein said failure is due to fatigue.

21. The apparatus of claim 19, wherein each said RVE microstructure-based failure
model comprises at least one random variable and wherein probabilistic methods are used to
25 provide values for said at least one random variable.

22. The apparatus of claim 19, wherein said simulating further comprises:
establishing an RVE life for each said RVE; and
using each said RVE life to produce a result related to said component life.

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23. The apparatus of claim 19, wherein each said at least one RVE microstructure-based
failure model was ascertained following steps comprising:

identifying a material microstructure in said RVE;

characterizing how damage interacts with said microstructure to provide at

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least one damage mechanism; and

creating a failure model for said material microstructure based on said at least one damage mechanism, said creating comprising:

finding a sequence said at least one damage mechanism works to damage said material microstructure;

5 getting for each said at least one damage mechanism one of a group of models consisting of: a crack nucleation model, a short crack growth model, and a long crack growth model; and

10 linking said models to produce said RVE microstructure-based failure model based on information from said identifying, characterizing, and finding.

24. The apparatus of claim 23, wherein said characterizing further comprises: determining said material microstructure's mechanical characteristics; and determining said material microstructure's bulk elastic material characteristics.

15 25. The apparatus of claim 23, wherein said finding comprises: determining how many of said at least one damage mechanism are crack nucleation mechanisms;

20 determining how many of said at least one damage mechanism are short crack growth mechanisms;

determining how many of said at least one damage mechanism are long crack growth mechanisms; and

25 developing a strategy for linking said crack nucleation, short crack growth, and long crack growth mechanisms.

26. The apparatus of claim 19, said simulating a component further comprising:

determining an RVE life for each said RVE, said determining an RVE life comprising:

30 evaluating a statistically determined number of nucleation sites within said RVE utilizing probabilistic methods.

27. The apparatus of claim 26, wherein said probabilistic methods comprise Monte Carlo (MC) methods.

35 28. The apparatus of claim 19, said identifying further comprising

obtaining a statistical distribution of said stresses at said significant nodes and said simulating a component further comprising:

determining an RVE life for each said RVE while using probabilistic methods to include a statistical distribution in said stresses.

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29. The apparatus of claim 28, wherein said probabilistic methods comprise Monte Carlo methods.

30. The apparatus of claim 19, wherein said component has regions of similar geometric detail and said simulating further comprises adding a spatial correlation for said regions.

31. The apparatus of claim 28, wherein said component has regions of similar geometric detail and said simulating further comprises adding a spatial correlation for said regions.

15 32. A method for determining the orientation factor for a grain slip system of a material, the method comprising:

obtaining equations that relate a stress direction to a material's at least one potential slip system;

simulating a grain orientation of said material, said simulating comprising:

20 using probabilistic methods to generate a slip plane normal angle for each said at least one potential slip system;

inputting said normal angle into said equations to obtain a potential orientation factor for each said at least one potential slip system; and

25 selecting the least said potential orientation factor as a grain orientation factor for said grain orientation;

repeating said simulating for a defined number of grains and obtaining a plurality of grain orientation factors; and

30 creating a statistical distribution of said plurality of grain orientation factors to determine an orientation factor for said grain slip system.

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33. The method of claim 32, said probabilistic methods comprising Monte Carlo methods.

34. The method of claim 32, said equations pertaining to titanium aluminide.

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35. An apparatus for determining the orientation factor for a grain slip system of a material comprising:
- a central processing unit (CPU);
 - an output device for displaying simulated fatigue results;
- 5 an input device for receiving input;
- and a memory comprising:
- instructions for receiving input;
 - instructions for simulating a grain orientation of said material, said simulating comprising:
- 10 relating a stress direction to each of a material's at least one potential slip system with equations;
- using probabilistic methods to generate a slip plane normal angle for each said at least one potential slip system;
- 15 inputting said normal angle into said equations to obtain a potential orientation factor for each said at least one potential slip system; and
- selecting a least said potential orientation factor as a grain orientation factor for said grain orientation;
- 20 instructions for repeating said simulating for a defined number of grains and obtaining a plurality of grain orientation factors; and
- instructions for creating a statistical distribution of said plurality of grain orientation factors to determine an orientation factor for said grain slip system.

36. The apparatus of claim 35, said probabilistic methods comprising Monte Carlo methods.

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37. The apparatus of claim 35, said equations pertaining to titanium aluminide.

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